



# Assessing the Quality of MODIS Polar Winds

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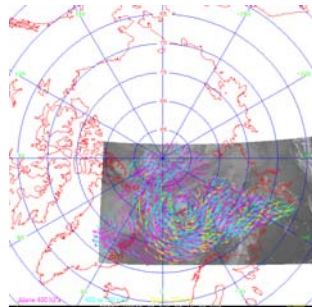
## Introduction and Background

Polar winds can be generated from imagers aboard low earth orbit satellites such as the NASA EOS and NOAA POES satellites. Since 2002, Moderate Resolution Imaging Spectroradiometer (MODIS) data has been used to generate near real-time wind information over both polar regions. Today, MODIS polar winds are generated operationally by NOAA's National Environmental Satellite, Data, & Information Service (NESDIS), and experimentally at three direct broadcast (DB) sites in the Arctic and Antarctic.

Wind derivation from MODIS data is based on the established procedure used for the Geostationary Operational Environmental Satellite (GOES) (Key et al., 2003; Velden et al., 2005). With MODIS, cloud features are tracked in the infrared window band at 11 μm and water vapor features are tracked in the 6.7 μm band using three consecutive orbits. These features are assigned heights via the infrared window and H2O-intercept methods (Neiman et al., 1993).

MODIS winds have been shown to have a positive impact on global weather forecasts by at least ten Numerical Weather Prediction (NWP) centers worldwide. Further improvement in the utilization and impact of these winds on NWP forecasts is possible through improvements made to the product algorithms. For MODIS winds and satellite-derived winds, in general, height assignment remains the most challenging component of the wind derivation process.

The purposes of this study are to 1) assess the quality of the MODIS winds generated at two direct broadcast (DB) sites relative to the quality of the MODIS winds generated operationally, and 2) assess the quality of the heights assigned to the MODIS winds through a Level-of-Best fit (LOB) analysis. The LOB is the RAOB level at which the vector difference between the MODIS wind and RAOB wind is at a minimum. Rawinsonde observations are used as ground truth. A similar analysis was performed by Daniels et al. (2004). However, those comparisons were done with GOES winds and over a shorter time period, while this one will be over several years, utilizing the archive of CIMSS winds (2002-2006).



Winds from Sodankylä, Finland for Day 2007232, 16:23 UTC.

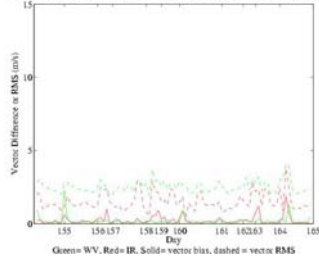
## MODIS Wind analysis

### Wind Generation Comparisons

- Nightly comparisons are performed, comparing the winds generated at CIMSS to winds generated at NESDIS and each of the DB sites (McMurdo, Antarctica and Tromsø, Norway). This is done to assess how winds from each site compare with each other.

- On average, the CIMSS winds have a small absolute vector difference when compared with the direct broadcast winds. This absolute vector difference, for both Terra and Aqua satellites and both water vapor and cloud-track winds, is below 1 m/s (solid line). In addition, the vector RMS of the CIMSS/DB wind comparison is 1-2 m/s for both types of winds (dashed line).

Vector Difference from SSEC and Tromsø, using Terra at NP, Tromsø DB



10 day time series of absolute vector difference and vector RMS for CIMSS vs Tromsø winds, using the Terra satellite

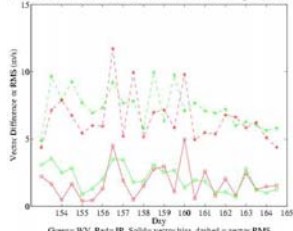
This analysis shows that the CIMSS and direct broadcast winds are nearly the same, so the CIMSS archive can be used in a long term level-of-best fit analysis.

### MODIS/RAOB Comparisons

A nightly analysis of the winds at each generating center compared with RAOB observations helps gauge the performance of each MODIS wind generation site with a ground truth measurement. The various generating sites using both satellites and types of winds have similar vector RMS and absolute vector differences. The average vector difference is around 3-4 m/s (solid line on figure below), and the vector RMS is 6-7 m/s (dashed line on figure below). These RMS values are typical for MODIS winds over the poles.

The reasons for this large variance include the large distance threshold that is used to compile the data (150 km) and time threshold (±90 min). Due to the sparsity of RAOBs, large distance and time thresholds are necessary. Another possibility is the time between the first pass and last pass use. Large jumps in the nightly comparisons are likely due to incomplete RAOB observations.

Vector Difference from RAOB and CIMSS winds, using AQUA at NP



10 day time series of absolute vector difference and vector RMS for CIMSS vs RAOBs, using the Terra satellite at the Arctic

## Level of Best Fit

The level-of-best fit (LOB) is defined as the level at which the difference between the RAOB and MODIS or AVHRR vector wind is at a minimum. It is determined by minimizing a cost function that consists of the vector wind difference and the differences in pressure and temperature:

$$C = (w_1 * abs(v_{diff})) + (w_2 * abs(P_{diff})) + (w_3 * abs(T_{diff}))$$

where C is the cost function,  $v_{diff}$  is the vector speed difference,  $P_{diff}$  is the scaled pressure difference and  $T_{diff}$  is the scaled temperature difference. The weights associated with each difference are  $w_1$ ,  $w_2$ , and  $w_3$ , and are 0.7, 0.15 and 0.15 respectively. The weights were determined experimentally.

The LOB analysis was performed over several years (2004-2006). A different level of best fit analysis was also performed using the Met Office model background wind column in place of the RAOBS (not discussed here).

The LOB analyses for each year were divided into wind type (IR or WV) and height assignment method (histogram, HIST, window channel, WIN, and H2O intercept, H2O). The sample were then compared using the Z-statistic to test the hypothesis that the LOB means were the same. It was found that there was no statistically significant difference in the best fit bias when comparing the same height assignment methods between each satellite and each of the years studied. However, the differences in mean LOBs for the two channels (IR, WV) and height assignment methods (histogram (HIST), window channel (WIN) and H2O intercept (H2O)) were statistically significant (0.02 level of significance). The table below shows the combined analysis of both satellites over the entire observation period of each height assignment method and type.

	Mean difference Arctic	Mean difference Antarctic	Mean overall difference
HIST (WV ONLY)	-9.68	0.36	-4.66
H2O (WV)	-40.32	-45.07	-42.69
H2O (IR)	-39.82	-39.65	-39.73
WIN (IR ONLY)	45.30	27.70	36.50

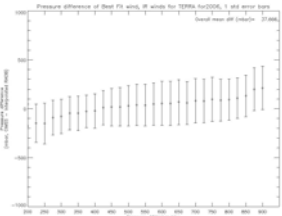
Table of differences between MODIS wind level and LOB for CIMSS winds from 2004-2006, by height assignment method and polar region.

The overall bias for all satellites, methods and wind types is -12.65 hPa, meaning that pressure of the LOB pressure is larger than the MODIS pressure.

- The HIST method showed the smallest best fit bias, with a difference of -4.66 hPa.
- The mean bias of the LOB for the AVHRR winds from NOAA-16 in 2002 is similar to that of the MODIS WIN method. This is the only method available for AVHRR winds.

The RMS for each bin is quite large, but consistent throughout the atmosphere.

- The LOB bias distribution for the IR winds from Terra in 2006 is shown below. The distribution is similar for all types of winds from both satellites.



The distribution of the difference between level of best fit and MODIS assigned height in 25 hPa bins for IR winds from Terra in 2006

At roughly 600 hPa, the difference between the level of best fit and the MODIS wind is nearly zero. At lower altitudes (higher pressures), the MODIS winds are slightly lower than the LOB. This is likely the result of different height assignment methods used at different levels (H2O-intercept at upper levels, and both HIST/WIN and H2O at middle and lower levels).

## Conclusions and Future Work

1. This study examined the quality of the MODIS winds generated at the two direct broadcast (DB) sites relative to the quality of the MODIS winds generated operationally and the quality of the heights assigned to the MODIS winds through a Level-of-Best fit (LOB) analysis.
2. The CIMSS and the DB winds are similar in quality.
3. The LOB analysis showed that the various wind types and height assignment methods were statistically different. It was found that the best method of assigning the wind height was the HIST method and the worst method was the H2O intercept method.
4. Future research includes identifying improvements to the H2O and IR window height assignment methods as well as understanding the large differences in the LOB analysis of the IR WIN method, which is used by the MODIS IR winds and for AVHRR winds.

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